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SEP 76 R BALES, G BEEKER, C BROGLIO, F CASEY

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CENTRAL FLOW CONTROL COMPUTER PROGRAM SPECIFICATIONS: VOLUME III OFF-LINE SUPPORT SUBSYSTEM SPECIFICATION

Central Flow Control Design Team
Federal Aviation Administration

September 1976
Final Report

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
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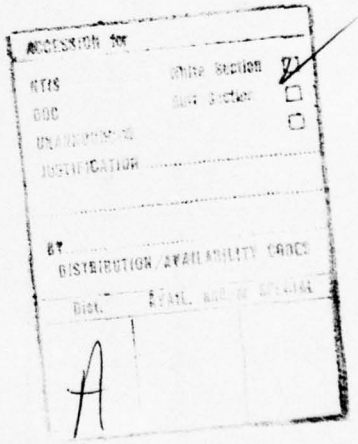
16. Abstract

This report contains the specifications for the off-line support subsystem of the Central Flow Control Computer Program. This report provides a detailed functional specification of the utility, data recording and analysis, data base support, system build, system test, and management aid software components of the system.



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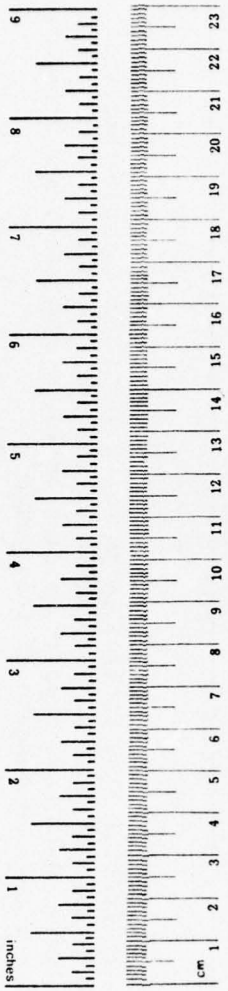
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

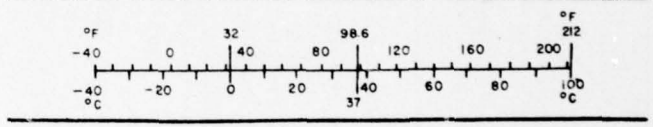
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ACKNOWLEDGEMENT

This specification series was prepared by the members whose names are listed above. In performing this work these members were supported by their respective organizations. Inclusion in the above list, however, does not necessarily imply that either the individual or his organization endorses the report.

CONTRIBUTING ORGANIZATIONS

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AAT - Air Traffic Service, Federal Aviation Administration
ARD - Systems Research and Development Service, Federal Aviation Administration
BDM - The BDM Corporation, Vienna, Virginia
FEDSIM - Federal Computer Performance Evaluation and Simulation Center
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1. INTRODUCTION

The CFC support system performs the off-line processing required in support of the CFC system throughout its development, implementation, test and maintenance. The functions provided by the CFC support system include the following capabilities:

a. Operational aids

Provide the capabilities needed to generate the operational system and to maintain a current data base. In addition, the Data Reduction and Analysis (DR&A) capability provides the means for automatic analysis of past system operations.

b. Development aids

Includes the software production tools to enhance the efficiency and the timeliness of the programming effort. Also, easy to use test tools are provided to support a comprehensive testing of the system prior to cutover and to verify new system versions during maintenance.

c. Control aids

Provides the tools needed to support the overall management of the project during the various phases, to maintain control over schedules and over the product quality, and to enhance communications between the various project teams.

The off-line system utilizes the redundant simplex with its related storage and peripherals.

The CFC support system will utilize many features of the existing NAS operational support system for the A3d2 NAS model. Many of the capabilities of the NAS support system, primarily the utilities group, will be used to support CFC. Various NAS support programs may require some modifications before they can be used

in CFC. In certain areas, for example system build, the concepts of the NAS support system are retained, but new programs must be written. These functional specifications, therefore, have been fashioned after the NAS functional specification (NAS-MD-347, 348, 349) and, whenever possible, provide excerpts or adaptations thereof.

1.1 Software

The off-line functions have been divided into five groups as shown in Figure 1-1. These are:

1. Utilities Group: Includes the operating system, the compiler, the assembler and similar processors which are required to facilitate the production, management and maintenance of programs and data for both the operational and the support systems.

2. DR&A Group: Provides the capability to reduce and analyze the data recorded during live operation. Comprehensive listings, summaries and statistical reports are produced to enable evaluation of past system performance.

3. Static Data Base Group: Assembles the static data base and the adaptation data that will be used on-line by the CFC system. The source data is read, analyzed, updated and prepared for use in building the operational system.

4. System Build Group: Provides the capability to generate and maintain an IPLable disk-resident CFC system. This system is constructed from the operational programs, the data bases and the user defined configuration parameters.

5. System Test Group: Facilitates program testing, evaluation, training and demonstration. The system test group provides the mechanism to drive the operational system with simulated data without employing the extensive resources required for a live configuration.

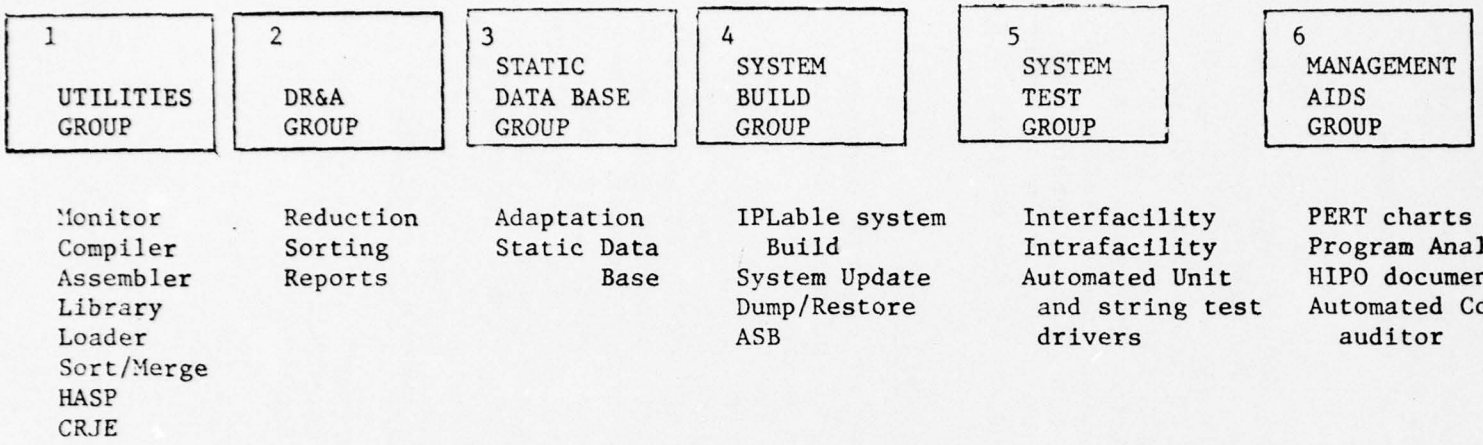

FIGURE 1-1 CFC OFF-LINE SUPPORT SYSTEM OVERVIEW

Note: Refer to the appropriate section in this document for a description of the functions included in each of the groups shown.

6. Management Aids Group: Provides the tools for maintaining control over the progress of the project during the design, implementation and maintenance phases. Functions are available to provide information on the schedules of the various efforts, the quality of the code and the structure of the programs.

1.2 Hardware

Table 1-1 lists the hardware requirements for the off-line support system. Normally, this hardware is used exclusively by the support system. Therefore, the support system processing can be carried out concurrently with the normal processing of the operational CFC system. However, in case of a hardware failure in the operational system, any of the hardware components can be preempted from the support system. This could result in aborting whatever processing is going on in the support system at that time.

1.3 Summary of Support Capabilities

Table 1-2 provides a summary of the CFC support capabilities. The table also indicates the status of the support functions in terms of their availability in the present NAS system. It is important to note that much of the existing NAS software, although not directly applicable to the CFC effort, can and should be utilized for CFC. As an example, the DR&A requirements (for recorded and reduced data) are different from those of NAS. However, those portions of the NAS DR&A programs which read and perform the initial processing of the on-line recorded tapes, analyze user specifications and prepare the final reports, can be applied to CFC with a relatively small programming effort.

1.4 Support Software Programming Requirements

The CFC support software programming effort includes all the programming requirements as specified in Attachment A (Programming Requirement) of the RFP.

TABLE 1-1

CENTRAL FLOW CONTROL

OFF-LINE SYSTEM HARDWARE[1]

Number	Element
1	Compute Element (CE)
1	Input/Output Computer Element (IOCE)
1	System Console
4	65K words Storage Elements (1 megabyte)
1	Disk Control Unit
5	Disk Drives
1	Tape Control Unit
8[2]	Tape Drives
1	High Speed Printer
1	Card Reader/Punch
4	Terminals (2 each FOB 10A and Jacksonville)
1	Transmission Control Device

(1) All the elements used in the off-line system will be available for configuration into the on-line system on demand.

(2) This is a recommended quantity. However the availability of 8 tape drives is questionable at this time.

TABLE 1-2 SUMMARY OF SUPPORT CAPABILITIES

	Group	Function[1]	Currently Available	Changes Required	New Program
1	Utilities	OS/9020	X		
		JOVIAL compiler	X		
		BAL assembler	X		
		Library Edit	X		
		JOVIAL structured programming listing formatter	X		
		JOVIAL source include processor	X		
		JOVIAL library capability	X		
		CRJE	X		
		HASP	X		
2	DR&A				X
3	Static Data Base	SDBA			X
		SADA			X
4	System Build	Sys Gen			X
		Sys Update			X
		Dump/Restore		X	
		ASB	X		
5	System Test	Inter			X
		Intra			X
		Automated unit and string test drivers			X
6	Management Aids	PERT	X		
		Program Analyzer			X
		HIPO	X		
		Automated Code Auditor			X

Note: 1. Refer to the appropriate section in this document for a description of the indicated functions.

In addition to these general requirements, the implementation of the CFC support system must include special recovery capabilities in order to make provisions for the eventuality that the support system is aborted due to the preemption of a hardware component by the operational system (see Section 1.2). This shall be accomplished by employing a checkpoint/restart facility in each support process with a time interval of 30 (SP) minutes. The recovery recording time, during a checkpoint operation, shall not exceed 3 (SP) minutes.

1.5 Document Organization

This document is self contained in the sense that it describes the complete processes performed on the off-line system. The six major sections of this document discuss each of the support sub-systems, as follows:

Section 2: Utilities
Section 3: DR&A
Section 4: Static Data Base Build
Section 5: System Build
Section 6: System Test
Section 7: Management Aids

2. UTILITIES GROUP

The Utilities Group includes a set of processors which are required to facilitate the preparation, management and maintenance of the operational system components and the support components.

The support system operates under OS/9020, a version of the IBM/360 Operating System tailored for the 9020 computers. OS/9020 provides a set of service programs including a linkage editor, a loader, a sort/merge program and various utilities for handling data and programs (e.g., transfer, copy, print, etc.).

A JOVIAL compiler and a BAL assembler are available under OS/9020. The JOVIAL library capability provides access to commonly used routines (e.g., mathematical, data conversion, etc.).

2.1 Monitor-OS/9020

2.1.1 Introduction

The OS control programs have three major functions: job management, task management and data management. Job management is the processing of communications from the programmer and operator to the control program. Task management includes the following functions:

a. Overlap of central processing unit operation with input/output channel activity

b. Servicing of all hardware interrupts

c. Handling of all supervisor calls (SVCs)

d. Allocation of main storage for programs and data

e. Dynamic loading of programs not in main storage

f. Synchronous overlay supervision

g. Recording of machine malfunctions

h. Servicing requests for writing CHECKPOINT records during the execution of a program and restarting programs at these checkpoints

Data management includes allocating space on direct access volumes, storing, naming, and cataloging data sets, and scheduling all I/O operations.

2.1.2 MVT Control Program

The Multiprogramming with a Variable number of Tasks (MVT) control program configuration is provided for use in a minimum of four logical SEs. MVT reads one or more continuous streams of jobs and schedules the jobs in order of priority. With this configuration up to 14 jobs can be performed concurrently with job-step-initiated tasks and operator-initiated tasks such as readers and output writers. Under MVT the control program assigns a region from a pool of available storage to each step as it is initiated. Upon completion of a job step, the region is returned to the pool for assignment to other job steps.

2.1.3 Service Programs

Service programs are provided under the MVT Control Program. The service programs consist of a linkage editor, a loader, a sort/merge program and a set of utility programs.

2.1.3.1 Linkage Editor

A linkage editor is provided for combining program segments that were individually compiled or assembled. The linkage editor forms a single program that is ready to be loaded into main storage and executed. It enables changes to be made in a program without recompiling the complete program; only those sections that are changed need to be recompiled.

2.1.3.2 Loader

The loader loads object modules produced by language translators and load modules produced by linkage editor into main storage for execution.

2.1.3.3 Sort/Merge Program

The sort/merge program is a generalized program that can be used to sort or merge records in ascending or descending order. The sorting and merging can be performed using magnetic tape and direct access storage devices for input, output, and intermediate storage. Execution of the sort/merge is initiated by control statements in the operating system input stream, or by another program through the use of macro instructions.

2.1.3.4 Utility Programs

These programs are used to:

a. Transfer, copy, or merge sets of data from one storage medium or I/O device onto another

b. Edit, rearrange, and update programs and data

c. Compare, print, or punch data

d. Create an input stream

2.1.2 9020 Modifications

2.1.2.1 Problem Areas

Four problems require solutions before either OS control program can be run in 9020 mode using native 9020 equipment such as the PAM. The problems are:

a. Physical channel 0 is the only valid specification for a multiplexor channel.

b. Storage with a storage key of 0 is unprotected on a 9020.

c. 1052 consoles, attached to a PAM, require the high order bit of the command code in the CCW to be on.

d. The high order eight PSW bits on a 9020 and a 360 are identical. On the 9020 bits 16-19 of the PSW are defined as system mask bits for physical channels 7-A. Consequently, the SSM (Set System Mask) instruction on the 9020 causes 12, as opposed to eight on the 360s, bits to be set in the PSW. The interruption code in the PSW is 12 bits on the 9020 opposed to 16 bits on the 360.

2.1.2.2 Modifications

Modifications required to resolve each of the problems described in Section 2.1.2.1 are explained in the following paragraphs:

a. Added Multiplexor Channels

On the 9020, channels 0, 4, and 8 are multiplexor channels. To correctly utilize a non-zero multiplexor channel in OS, patches exist in the OS input/output supervisor (IOS). The patches were applied to the Test Channel and Channel Search Routines in IOS.

b. Storage Protection

On a 360, OS will assign a zero storage key for the control program. To provide control program protection for OS on the 9020, a storage key of one was assigned to control program storage. The storage validity check routines in IOS are modified to assume keys of zero or one are control program storage. In OS/MVT the logic in GETMAIN/FREEMAIN (dynamic storage allocation module) is appropriately modified. Control program storage requests are assigned a key of one. Problem program storage requests are processed as if it were a 360. Released storage is returned to the available storage pool with a key of one. The technique used in MVT imposes a procedural restriction such that the maximum number of job initiators is reduced from 15 on a 360 machine to 14 on a 9020.

c. PAM 1052 Capabilities

The system console I/O modules are simply modified to assure the presence of the high order bit in the I/O command code. In addition, the IPL logic is modified to assure the proper command code.

d. 9020 System Mask Sensitivity

Both the I/O and SVC interrupt handlers in OS assume bits 16-19 of the old PSW are zero. The execution of the SSM instruction in OS is numerous and, consequently, the low order mask bits in the PSW are unpredictable. The initial logic in both the I/O and SVC first level interrupt handlers is modified to clear bits 16-19 of the old PSW, stored at interrupt time.

2.2 JOVIAL Compiler

The JOVIAL compiler translates JOVIAL source into Basic Assembly Language (BAL) code for subsequent processing by the Assembler.

2.2.1 Function

2.2.1.1 BAL Source Generation

During compilation, the compiler checks all JOVIAL source program statements and issues diagnostic messages when errors are detected. When library routines are requested in the source program, the compiler accesses a disk resident library Procedure Descriptor Table (PDT) to generate the required parameter list and library calling sequence.

If a compool is requested, the compiler fetches the specified compool tables data set from disk.

The compiler is finished when it has generated a sequential data set of BAL source statements from the input JOVIAL source. The BAL assembler is invoked as a separate job step following successful completion of the JOVIAL compiler.

2.2.1.2 JOVIAL Source Syntax Check

The JOVIAL source syntax check is invoked via the JOVIAL option, SYNCK. When operating in syntax check mode, the compiler will terminate after the first phase, producing a listing with the diagnostic messages immediately following the statement in error.

2.2.1.3 Compool Generation

When this option is selected, source input to the compiler consists entirely of data declaration statements. The compiler will generate a new, disk resident compool consisting of three data sets (compool tables, compool reserves and compool object decks).

2.2.2 Input

Programs written in the JOVIAL language are the primary input to the compiler. In compool generation mode, input is restricted to JOVIAL data declarations for arrays, tables and their strings and/or item definitions (with or without preset constants), and parameter items. The compiler will be invoked by standard catalogued procedures of job control language. One procedure will be provided to invoke the BAL source generation or syntax checking functions of the compiler. A second procedure will be used to generate a compool.

Major options of the compiler are:

a. List data references by name

b. Punch .XRF cards for LIBRARY calls and/or compool data references

c. Perform source syntax check

d. Generate a compool

2.2.3 Output

Compiler output varies according to the function being performed. The following sections itemize the outputs of each function.

2.2.3.1 BAL Source Generation

a. JOVIAL source listing

b. BAL source statements and requests for compool segments

c. Errors and diagnostics

d. Cross reference listing

e. Punched deck of XREF cards

2.2.3.2 JOVIAL Source Syntax Check

a. JOVIAL source listing with diagnostic messages immediately following the statement in error

2.2.3.3 Compool Generation

a. Listing of compool

b. Diagnostic messages

c. Three disk resident data sets

1. Compool Tables

2. Compool Reserves

3. Compool Object Decks

2.3 BAL Assembler

The BAL Assembler translates BAL statements into loadable object decks.

2.3.1 Function

The 9020 Assembler translates BAL input into object decks. An object deck is a loadable module. It includes binary equivalents of the BAL source and linkage information for programs separately assembled that are to be loaded and executed together.

The Assembler is invoked as a separate jobstep by the OS control programs as a result of an // EXEC PGM=BAL card. A catalogued procedure containing the required job control language (JCL) will be provided for calling BAL.

The BAL Assembler accesses the compool reserves data set if requested via a CMPRSV DD statement. FINDS are issued for all compool segments requested via BAL PSEG cards and the appropriate members of the reserves are included in the assembly.

When PUNCHC is requested, the Assembler provides INCLUDE CMPSEG (ZX segnam) cards to the OS linkage editor. The linkage editor will then include the required compool object decks when constructing an executable load module.

2.3.2 Input

a. BAL options provided in the PARM of the // EXEC PGM=BAL card which invokes the Assembler

b. Assembly language source statements in the sequential data set defined via the SYSIN DD statement

c. Partitioned data set of compool reserves containing one member for each compool segment

2.3.3 Output

a. Listing of input source, assembled code, and diagnostics

b. Object decks containing:

1. Program Text

2. External Symbol Dictionary (ESD) Information

3. The Relocation Dictionary (i.e., address constants that must be changed if the program is loaded at a location different than the assembled address)

4. .LIB cards required to construct a JOVIAL library

c. Cross-reference listing

d. Punched cross reference information for compool data and library programs

e. Object decks and optionally, INCLUDE cards for the OS linkage editor if the LOAD option is requested

2.4 Library Edit

The library edit creates a disk resident library of common subroutine and procedures. Routines may be added, deleted, or replaced in the library.

2.4.1 Function

The library edit is used to generate and maintain a library of routines which are available to JOVIAL and BAL programmers. The library edit program is used to create a new library or to add routines to (or delete routines from) the existing library. To replace a library routine, the old routine must first be deleted and the new routine added. Catalogued procedures of job control language will be provided to allocate and catalog PDT and FSD data sets, delete and uncatalog obsolete PDT and FSD data sets, generate a new library and update an existing library.

2.4.2 Input

Input to the library edit program consists of control cards, object decks for routines being added or replaced and three pre-allocated library data sets. The library edit program will be invoked by a // EXEC LIBEDTN card when a new library is being generated and by a // EXEC LIBEDTR card when an existing library is being updated.

2.4.3 Output

a. Listing and diagnostic messages. An option is provided to request ESD and PDT information for all routines in the library. If omitted, ESD and PDT information will be printed only for library routines being added.

b. A new or updated disk resident library consisting of the following three data sets:

1. A sequential PDT data set containing the information required by JOVIAL to generate calling sequences to the library routines.

2. A sequential ESD data set containing external symbol dictionary information.

3. A partitioned data set of library routine object decks.

2.5 JOVIAL Structured Programming Listing Formatter

2.5.1 Function

The JOVIAL listing formatter provides automatic indentation of JOVIAL source code which conforms to the structured programming listings.

2.5.2 Input

Input to the listing formatter consists of JOVIAL source statements. JOVIAL code may be either structured or unstructured.

2.5.3 Output

Output from the listing formatter is a printed listing which conforms to the indentation standards for JOVIAL structured programming. The indentation conventions are designed to produce a JOVIAL listing which is easy to read, maintain and modify.

2.6 JOVIAL Source Include Processor

2.6.1 Function

The JOVIAL Source Include Processor provides the capability to include JOVIAL source statements from other sequential or partitioned data sets into a data set for input to the JOVIAL Compiler.

2.6.2 Input

Input to the JOVIAL Source Include Processor is:

a. A data set containing the JOVIAL source program with JOVIAL Include control statements

b. Sequential and/or partitioned source data sets to be included into the JOVIAL program. These secondary inputs may contain JOVIAL source and JOVIAL Include control statements.

2.6.3 Output

The JOVIAL Source Include Processor provides two outputs:

a. A JOVIAL source data set that will be input to the JOVIAL Compiler

b. A sequential message data set which contains a listing of all primary inputs, optionally, all secondary inputs, and all error messages. The listing is formatted according to the structured programming indentation conventions.

2.7 JOVIAL Library Capability

A JOVIAL library will be provided for use by the off-line support systems. The OS/9020 JOVIAL and linkage editor access a disk resident library generated by the OS version of the library edit program. The library routines can be classified according to purpose. They include mathematical, data conversion and movement, data comparison, input/output, unit positioning, and initialization routines. Section 2.7.1 lists these library routines and provides a brief functional description.

The JOVIAL compiler uses tabulated information generated by the library edit program to determine the routines needed and their parameter requirements. It generates an external symbol for each requested library routine and produces the required parameter list and calling sequence. Under OS, the automatic call feature of the linkage editor causes the required library object decks to be included in the load module from the partitioned data set of library object modules furnished via the SYSLIB DD statement.

2.7.1 OS/9020 Library Routines

2.7.1.1 Input Data Conversion

Routine	Function
ASCIN	Translate EBCDIC to ASCII
FLTFL	Convert from EBCDIC floating point to internal floating point
FLTINJ	Convert from EBCDIC floating point to internal floating point
HEXIN	Convert from EBCDIC hexadecimal to internal binary
HOLFL	Access EBCDIC field without alteration
HOLINJ	Direct access of EBCDIC field without alteration
INTFL	Indirect conversion from EBCDIC integer to internal binary integer
INTINJ	Direct conversion from EBCDIC integer to internal binary integer

2.7.1.2 Output Data Conversion

Routine	Function
ASCOUT	Translate ASCII to EBCDIC
FLTOTJ	Convert from internal floating point to EBCDIC floating point
HEXOUT	Convert from internal binary to EBCDIC hexadecimal
HOLOTJ	Move EBCDIC field without alteration
INTOTZ	Convert from binary integer to EBCDIC integer with leading zeros
INTOTJ	Convert from internal binary integer to EBCDIC integer
MIXOTJ	Convert from internal fixed point (scaled to integer) to EBCDIC fixed point

2.7.1.3 Data Conversion and Movement

Routine	Function
MVC	Move data between identically sized character fields
TMTR	Execute TRT plus move and TR
TR	Translate character data from one code to another according to a user-supplied translate table
TRT	Test character data by executing a TRT instruction and returns the address of the first non-zero byte
TSET	Execute a Test and Set instruction and returns a 0 or 1 condition code
TSTR	Execute TRT and TR in sequence

Routine	Function
LEFTJ	Left-justify Hollerith data that are right-justified with leading zeros
MVI	Move an immediate character field into an address
MVM	Move a character field of a specified length from one address to another address
MVT	Return a character field of a specified length from an address as the function output value

2.7.1.4 Data Comparison

Routine	Function
CLC	Compare two equal length strings of characters. The arguments specify the locations of the two fields and their length
CLI	Compare two equal length strings of character. The second field is an argument rather than the address of an argument

2.7.1.5 Mathematical

Routine	Function
ARCOS	Compute angle in radians from its cosine
ARCSIN	Compute angle in radians from its sine
ARCTAN	Compute angle in radians from its tangent
ARCTND	Compute heading in degrees from its X and Y components
ARCTNP	Compute heading in Azimuth Change Pulses (ACPs) from its X and Y components

Routine	Function
ATANFP	Similar to ARCTNP but accept floating point input
COS	Compute cosine for angle expressed in radians
CSINE	Compute sine and cosine for angle expressed in ACPs
EXPON	Compute a number from its natual log
LOGN	Compute the natural log of a number
RANDOM	Generate a pseudo random floating point fraction
RANINT	Generate a pseudo random integer within a provided range
SIN	Compute the sine for an angle expressed in radians
SQRT	Compute the square root of a positive number

2.7.1.6 Compiler Called Routines

Routine	Function
EXPFF	Convert floating point base to floating point exponent
EXPFI	Convert floating point base to integral exponent
FIX	Convert floating to fixed
FLTA	Convert fixed A-type to floating
FLTI	Convert fixed integer to floating

2.7.1.7 Data Set Initialization

Routine	Function
OPEN	Logically connect a data set (QSAM)
SHUT	Logically disconnect a data set (QSAM)
SETRET	Set I/O return
DCBQ	Define QSAM Data Control Block

2.7.1.8 I/O Positioning

Routine	Function
CNTRL	Control on-line magnetic tape file positioning

2.7.1.9 I/O Input

Routine	Function
GET	Obtain next logical record (QSAM)
VGETR	Unblock variable blocked input data and return address logical record (QSAM)

2.7.1.10 Data Output

Routine	Function
WTO	Write to operator
WTOR	Write to operator with reply
PUT	Write next logical record (QSAM)

2.7.1.11 Main Storage Supervision

Routine	Function
GETCOR	Allocate main storage
FRECOR	Release allocated main storage

2.7.1.12 Miscellaneous

Routine	Function
CORE	Core dump in hexadecimal and EBCDIC
FLTFLD	Scan a character sequence to locate individual data fields and store field descriptions in a table for the caller
LOCW	Provide the address of any table or array as a word value
MODULO	Produce an output that is equivalent to input module 14400
TIMDIF	Accept an input time and produce its equivalent with absolute value less than 7200

2.8 Conversational Remote Job Entry (CRJE)

CRJE* operates under OS/9020. It provides Remote Job Entry capability for users at remote keyboard terminals that are connected to the 9020 via communication lines. Users can prepare and enter jobs for background processing under the operating system at the central installation. Remotely submitted jobs are scheduled, initiated, executed, and terminated under the control of the OS job management routines. Thus, a remote CRJE user has the same batch-computing facility that is available for a local user. Through background processing of jobs submitted through CRJE, users have access to the full facilities of OS/9020.

Job input consists of programs and data that are conversationally created and maintained through the facilities of CRJE. Lines of program source statements, data, and job control language are collected

* Note: this description of CRJE was largely extracted from IBM form GC30-2012-1.

within the central system as the user types them at a remote keyboard terminal. There is no need for keypunching, nor is there the waiting time for operator handling and card reading. Simple correction procedures make it easy to get data entered without typing errors.

Operating on-line with the system greatly reduces job turnaround time, since data is transmitted directly between the central processor and the terminal, with no intermediate devices such as card readers and printers. To submit a job for execution, the user just selects the program, data, and job control statements to be entered into the OS input stream. As soon as the job is completed, the user can examine the output at any terminal.

Data entered from a terminal can also be saved at the central installation for subsequent use. Stored data can be easily retrieved for on-line displaying and modifying as well as be specified as part of job input to the operating system. A user can update his stored data by inserting, replacing, deleting, and changing single lines or groups of lines. CRJE provides protection against unauthorized access of stored data as well as a means for users to share data.

In addition to facilities for job preparation, job entry, retrieval of job output, and manipulation of programs and data, CRJE provides the terminal user with information about his data sets and the status of jobs he has submitted. There is also a message facility for two-way communication between terminal users and the operator of the central computer.

2.9 Houston Automatic Spooling Program (HASP)

HASP operates in conjunction with OS/9020. It performs peripheral functions, not normally accomplished by OS/9020, by stealing small amounts of CPU time to operate the printers and the reader/punch, while operating in direct communications with OS. HASP also controls the job flow, ordering of tasks and the spooling of inputs and outputs.

3. DR&A GROUP

The DR&A programs provide the capability to perform off-line processing of data recorded on tape and/or disk during live operation of the CFC system. A variety of DR&A programs shall be available to reduce, sort and analyze the on-line recorded data and to provide clear and concise reports, statistical data listings and plots on past system performance. The DR&A user specifies, through input commands, which components of the DR&A group shall be executed and in what order. The DR&A capability must be easy to use, flexible, easily expandable, efficient and as automatic as possible from the standpoint of operations.

3.1 General

A conceptual flow of the DR&A subsystem is shown in Figure 3-1. The input, processing and output functions are described as follows.

3.1.1 Input

Input to the DR&A subsystem will consist of magnetic tapes and/or disk and user control cards. The tape/disk normally contain raw data recorded during the actual running of the operational system.

In some cases the tape/disk may contain data which was previously processed by other DR&A programs. The user control commands and parameters select the desired program and specify various user options and parameters. Where possible, a missing card input item will be filled in automatically assuming predefined defaults.

3.1.2 Processing

All DR&A processing will be performed under control of the DR&A Executive. This Executive will schedule and initiate all the DR&A subprograms which are needed to successfully carry out a complete DR&A run. The DR&A subprograms will include the following modules:

a. Read and process input cards

b. read tape/disk recorded data

c. Sort/merge/compare the raw data

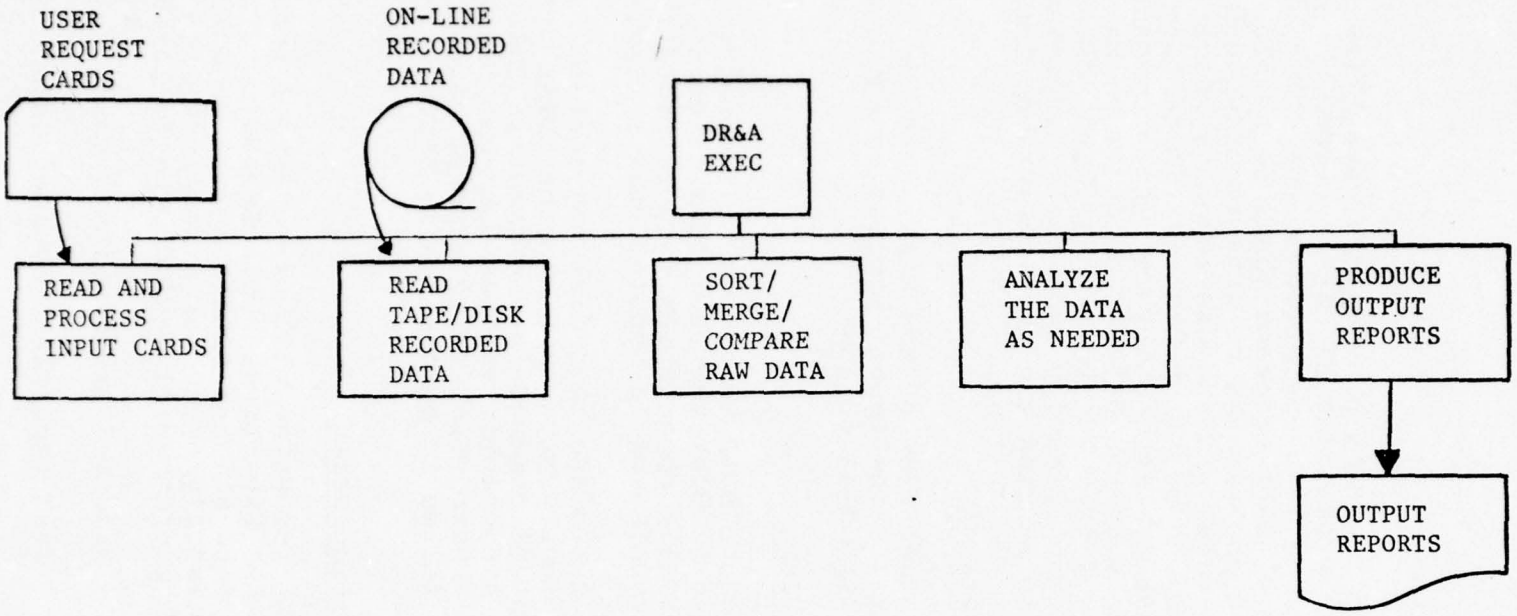

FIGURE 3-1 DR&A

d. Analyze the data according to the required function

e. Generate the output report and print on the output device(s)

3.1.3 Output

The output consists primarily of a printout of the requested DR&A reports. In addition, general information will be provided containing identification of the run requested, the date, the input tape identification, the system version used, and page header and title. The input control cards will also be listed together with all applicable default parameters. Diagnostic messages, and user alerts if any, will be clear and informative.

3.2 DR&A Functions

This section describes some of the output reports that will be produced. These are:

a. Input/Output log

b. Data base analysis

c. Input/Output message summary

d. Response time summary

e. Log comparison function

f. Performance and activity measures

g. General Recording Data Processor

3.2.1 Input/Output Log (IOLOG)

The IOLOG function will provide a listing of all input and output messages which have been recorded on tape during CFC operations. IOLOG will determine, when possible, the message type, source and destination identity, and time. Certain messages will have their contents interpreted into more meaningful information. This information will be displayed in a legible output format.

IOLOG will be able to filter and sort the data according to user selected parameters. The manner in which data is filtered and/or sorted will be any combination of the following:

a. Start/Stop Time

b. Message type

c. Message source

d. Message destination

e. Airport/center ID

The user can specify what each report should or should not contain.

3.2.2 Data Base Analysis (DBA)

The DBA function will provide the capability of recreating all dynamic tables at any desired point in time. These tables will be reconstructed from the data recorded on-line and from messages that would effect changes to these tables. After the tables have been reproduced, the user has the option to obtain complete or selective listings of the data.

3.2.3 Input/Output Message Summary (IOSUM)

The IOSUM function will summarize all or selected input and output messages to and from the operational CFC system. Reports are produced in a legible format displaying summaries and statistical information on the volume and distribution of input and output messages.

The selection of the input/output messages is according to the following criteria or any combination thereof, as specified by the user:

a. Start and/or stop time

b. Type of message

c. Message source/destination

d. Airport/center ID

e. Type of report desired

The following data will be accumulated to provide, according to the type of report desired, the following statistics: total message counts, average message rate (i.e., messages per parameter time), min, max, standard deviation and histograms of messages in equal time intervals. These statistics can, at the user option, be for all messages or they can be broken down by any combination of the following:

a. Message type

b. Message source/destination

c. Airport/center

3.2.4 Response Time Summary (RTSUM)

The RTSUM calculates and produces summary reports on the amount of time required by CFC to produce an output message in response to an input message.

The program uses the output from the Input/Output Log function as a basis for the analysis. Only successful attempts to correlate input/output messages will be used to compute the following response time statistics:

a. Sum

b. Mean

c. Maximum

d. Minimum

e. Standard deviation

f. Frequency distribution

The above statistics will be produced pertaining to all messages which have been selected by the user. In addition, if the user desires, the statistics can be broken down by any combination of the following:

a. Type

b. Source

c. Time intervals

A matched input/output message report and unmatched message report may also be produced at the user option.

3.2.5 Log Comparison Function (LOGCOMP)

The LOGCOMP function provides a means of comparing two sorted edited on-line recorded tapes and providing a legible formatted output listing noting any discrepancies in the records of the two compared tapes.

Various options are available to the user in order to suppress reporting of irrelevant errors. Tape records to be used in the comparison can be selected or filtered out as specified by:

a. Time intervals

b. Records types

c. Message types

d. Message source/destination

In addition, "time error" tolerances of the matched records can be specified.

A printout of all the current records will be optionally provided. In addition, a summary of total error found will be printed out containing totals of matches and no matches.

3.2.6 Performance and Activity Measures (PMAM)

The PMAM function provides the means for analyzing the operational system hardware and software performance from the viewpoint of timing, utilization and workload of the various system components. This capability can be useful for detecting and eliminating potential bottlenecks and to support system tuning to improve performance. The following is a generalized list of the measures that will be provided:

a. Utilization of each CE, SE, IOCE, DCU, TCU, I/O devices, etc.

b. Utilization and frequency of activation of major CFC subprograms

c. Summary of issued I/O, external and SVC interrupts

d. Queuing statistics on major system queues

e. Sizing reports on dynamic buffers in main memory

f. Sizing reports on storage areas on disk and tape

3.2.7 General Recording Data Processor (GRDP)

The GRDP function provides a general purpose data reduction capability which the user can obtain according to his unique requirements.

The control information provided by the user specifies the data records to be processed from the on-line recorded data. This information will include the identification of the data records to be processed and the time of the recordings of interest.

The records will be identified by one of the following ways:

1. By a symbolic name or unique identifier

2. By an identification common to a set of records

3. By an input code which will indicate all records

In the first case, only those records with the specific name or identifier will be processed; in the second, only records which belong to the set having that identification will be processed; and in the third, all records will be processed. This assumes that all records meet the specified time of interest criteria.

The time of the recordings of interest will be specified by:

1. A time interval of recording, or

2. Every recording, i.e., no restrictive specification with respect to the time interval.

The output will include a listing of the selected records from the on-line recorded data. In order to reduce the amount of printing, whenever a line of output is identical to the previous line, it will not be printed. Instead, a symbol will be printed which will indicate this fact, and the number of lines which are identical will be indicated. For example, if the block consists of 100 words of which words 1 and 100 are the value 1 and the remaining words have the value 0, then the formatted output might be:

Word	Value
1	1
2	0
.	.
100	1

In addition diagnostic messages will be provided for unprocessed data blocks, if any. These messages will include a dump of the unprocessed records and the reason for the failure to process.

The program will have the capability of processing all types of records encountered in the on-line recorded data.

4. STATIC DATA BASE GROUP

The purpose of the Static Data Base Group is to assemble the static data base and the adaptation data that will be used on-line by the CFC system. The static data base is constructed from the OAG tapes (Reuben Donnelley tapes) and from other related data (e.g., airlines, aircraft types, etc.). The adaptation assembler processes geographical and system configuration data into a format which can later be used in building the operational CFC system. This group of programs reads the source static data base and the adaptation data, performs error checking, extracts and rearranges the source inputs, and produces the object text suitable for future computer processing. User oriented statistics and summaries are printed in accordance with user requests. In addition, a capability is provided to easily update the static data base and the adaptation data as needed.

Figure 4-1 is a functional representation of the two major static data base build processors.

4.1 Static Data Base Assembler

The Static Data Base Assembler (SDBA) is an off-line program which will generate and update the various CFC static data base files accessed during on-line operations.

The kinds of CFC data which are handled by SDBA include, but are not limited to, the following:

a. Air-carrier flight schedules

b. Airport data

c. Airline codes

d. Aircraft types

e. ARTCC data

f. Zone data

g. General aviation data

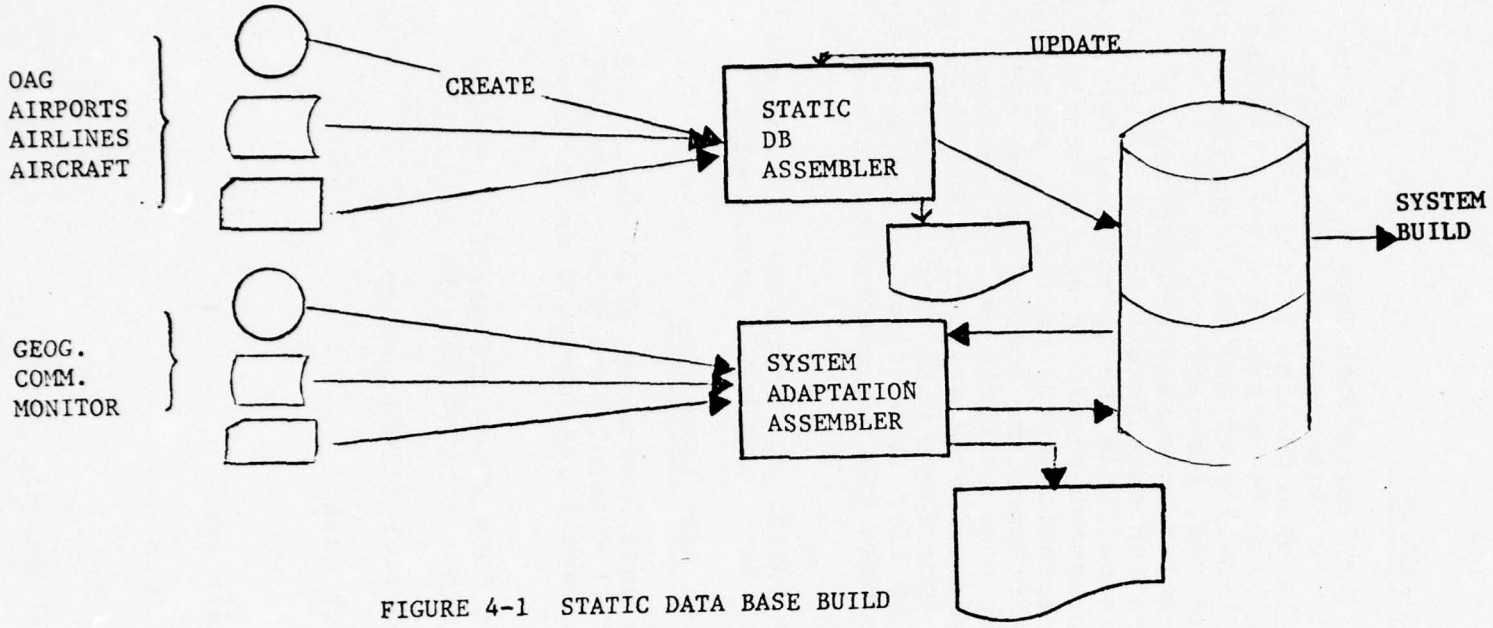

FIGURE 4-1 STATIC DATA BASE BUILD

The primary input to SDBA are the OAG data tapes (produced by the Reuben Donnelley Corp.). In addition, necessary data is provided through input tapes and/or cards. Processing is determined through user control cards specifying the required SDBA function and identifying the run parameters. SDBA checks the legality of the input data and insures the validity and completeness of the new files. The user is notified if errors are found.

4.1.1 Program Modes of Operation

There are three modes of operation (Assemble, Update and List) of the SDBA program. The Assemble mode is used initially to create a new data base. The Update mode provides the capability to add, change and delete information stored on the data files. The List mode produces a listing of the data base according to user options.

4.1.2 Input

The SDBA program accepts one or more of the following types of input data depending upon the mode of operation specified on the program control card:

a. program control cards

b. ADD cards

c. CHG cards

d. DEL cards

e. tapes (e.g., OAG tapes) and/or cards containing the data to be assembled

Where card input is required, the user will have the option to input card images from magnetic tape.

4.1.2.1 Program Control Cards

The Program Control Cards contain the following data fields:

Field 1: indicates the mode of operation - AS (assemble), UP (update), or LI (list)

Field 2: identifies the user, the date and contains a concise description of the run

Field 3: specifies the requested outputs (e.g., type of listings, output device, etc.).

4.1.2.2 ADD Cards

The ADD card is used in the Assemble or Update mode to enter data (e.g., flight plans) into the static data base. The following data fields will be provided by the user:

Field 1: the characters "ADD" along with any optional user identification

Field 2: the file to which the addition is made

Field 3: the data to be added (may extend over several cards)

4.1.2.3 CHG (Change) Cards

The CHG card is used in the Assemble or the Update mode. The purpose of this card is to modify the data contained in the data base. The following fields are included:

Field 1: the characters "CHG" along with any optional user identification

Field 2: the file in which the modification will be made

Field 3: the data which is to be changed

Field 4: the new data

4.1.2.4 DEL (Delete) Cards

The DEL card is used in the Assemble or the Update mode. The purpose of this card is to delete data from the data base. The following fields are included:

Field 1: the characters "DEL" along with any optional user identification

Field 2: the file in which the deletion will be made

Field 3: the data which is to be deleted

4.1.2.5 Tape/Card Input

In the Assemble mode the input data from which the data base will be generated consist of tapes (e.g., OAG tapes) or disk files and, optionally, cards (e.g., zone data). Any data read from cards can also be prestored on tape and the tape may be read in during the Assemble mode instead of cards.

4.1.3 File Organization

(to be specified)

4.1.4 Output

The SDBA program produces the following types of output:

a. error messages (if any)

b. listings

c. new or updated data base

4.1.4.1 Error Messages

Validity checking will be performed on all input data. If an error is found, a self explanatory error message will be printed out.

During the processing of the Assemble, Update and the List mode the program will report on all error conditions such as: unreadable data, missing data, ambiguities between the data base contents and user requested updates, etc.

4.1.4.2 Listings

The output listings will contain, according to the user option, a printout of the user input cards and a printout of data extracted from the data base.

In the Assemble and the Update mode, the user can request a listings of any newly created file(s). The List mode is for the purpose of obtaining such a listing from an existing data base on tape or disk. The produced printout will be in a readable form. It will also include the identification of the data base used.

4.1.4.3 New Data Base

The major output from the Assemble and the Update mode is the newly created data base. The new data base will be produced on tape or disk and will be in a form ready to be integrated within the CFC system during the system build process. A header record on the tape or disk will identify the new data base version.

4.2 System Adaptation Assembler

The System Adaptation Assembler (SADA) is an off-line program to adapt CFC to the system configuration requirements. The user input to SADA specifies, in a simple and clearly readable form, the environment under which CFC will operate. SADA processes this data, checks it, and produces the system adaptation data base. This data base is in object module form, and is readily available to be used by the system build processors to generate the operational on-line CFC system. SADA also provides the capability to modify and update an existing adaptation data base. As an option, SADA provides various output listings with user oriented information.

4.2.1 Adaptation Data

The adaptation data is divided into the following subsets:

a. Geographical adaptation

b. Communications adaptation

c. Monitor adaptation

4.2.1.1 Geographical Adaptation (GA)

The GA tables contain geographical data on the following:

a. airports

b. ARTCCs

c. fixes

d. airways

e. zone structure

4.2.1.2 Communications Adaptation (CA)

The CA tables contain data related to the communication network linking the CFC computer, the ARTCC computers, and the SCC facility. The following data is needed:

a. line connections

b. line characteristics (speed, capacity, etc.)

c. buffer storage

d. number of retransmissions

e. I/O devices

4.2.1.3 Monitor Adaptation (MA)

The MA tables contain data used by the monitor pertaining to the operational on-line CFC system. These data include but are not limited to:

a. on-line recorded data

b. recovery recordings

c. program priorities

d. timing data

e. logical device numbers

f. output message routing

g. security locks and authorized passwords

h. startup/startover tasks

4.2.2 Program Modes of Operation

SADA operates under three user-defined modes: Create, Update and List. The Create mode is used to generate a new output master text file. The Update mode specifies that certain selective changes are to be incorporated in the master text files. The master text file is used by the system build processor to generate the operational CFC system. The List mode specifies that a listing is to be prepared of some or all of the adaptation data.

4.2.3 General Function

In the Create and the Update modes, SADA will accept symbolic source input defining the adaptation data. Adaptation input will be divided into logical groups of data. SADA will process each input group, checking for its validity and correct format, and perform initial input data processing. After all input data has been successfully validated and initial data processing completed, SADA will begin generation of intermediate work files until all input data has been processed. Output generation will then be performed with the generation of object form text files on disk or tape to be used in system build.

In the List mode the program scans the previously prepared SADA files for the required information and produces the necessary listing in logically structured and readable format.

User control cards must be provided to specify the required mode and various run parameters.

4.2.4 Input

The input consists of user-specified run parameters, adaptation data to be assembled and old adaptation master files to be updated.

4.2.4.1 Run Parameters

The run parameters card or tape input includes the following information:

a. mode (Create, Update or List)

b. run identification

c. requested listing of input data

d. requested listing of output data

4.2.4.2 Master Adaptation File

These data are contained on disk or tape, and are used in the Update and List modes.

4.2.4.3 Adaptation Data

This data is provided in source form on tape or cards, and is used either to build a new master file or to update an existing master file. The adaptation data is grouped and sorted in order to reduce SADA processing time. The groups of data are:

a. geographical data

b. communications data

c. monitor data

Each group is preceded by a header card (or record) identifying its contents.

4.2.4.4 Data Updates

The data updates cards or tape entries specify additions (ADD header), deletions (DEL header) or changes (CHG header) to the master file records.

4.2.5 Adaptation Master File Organization

(to be specified)

4.2.6 Output

A SADA run may produce the following outputs:

a. New master file

b. Listings

c. Error messages

4.2.6.1 Master File

The new master file is produced on tape or disk and is readily useable by the system build processor in generating the operational CFC system.

4.2.6.2 Listings

The following complete or partial listings in logically structured format are produced according to user specified options.

a. Input data listings

b. Listings of the adaptation master file

c. Listings of the changed adaptation data (in the Update mode)

4.2.6.3 Error Diagnostics

This output will provide a list of error diagnostics which will identify, to the extent possible, the specific data in error, the error number and a concise description of the error.

5. SYSTEM BUILD GROUP

The System Build Group provides the capability to generate and maintain an IPLable disk-resident CFC system. User options and parameters are furnished to permit selection of hardware, software, storage areas, and the overall system environment. The preassembled static data base is incorporated during the system build process in the disk-resident CFC system. As an option, a system build run will produce printouts describing the newly built system configuration, cross reference listings and statistical data. A system update capability shall also be provided to facilitate an efficient updating of the disk-resident system and data base. In addition, an off-line program shall be provided to create transportable and backup copies of the disk-resident system. The system can thus be "dumped" on magnetic tape or disk and subsequently "restored".

5.1 CFC System Generation

Support programs will be required to generate an IPLable disk-resident CFC operational system. A functional description of the system build processor is shown in Figure 5-1.

5.1.1 Input

Input to the system generation program will include:

a. data sets on tape or disk containing the complete set of CFC operational programs in object deck form

b. 9020 system library routines

c. adaptation file containing geographical and system configuration data

d. a set of user specified system parameters defining the hardware, software, storage areas and the overall system environment.

e. static data base file(s) which have been previously checked and processed by the off-line static data base assembler program.

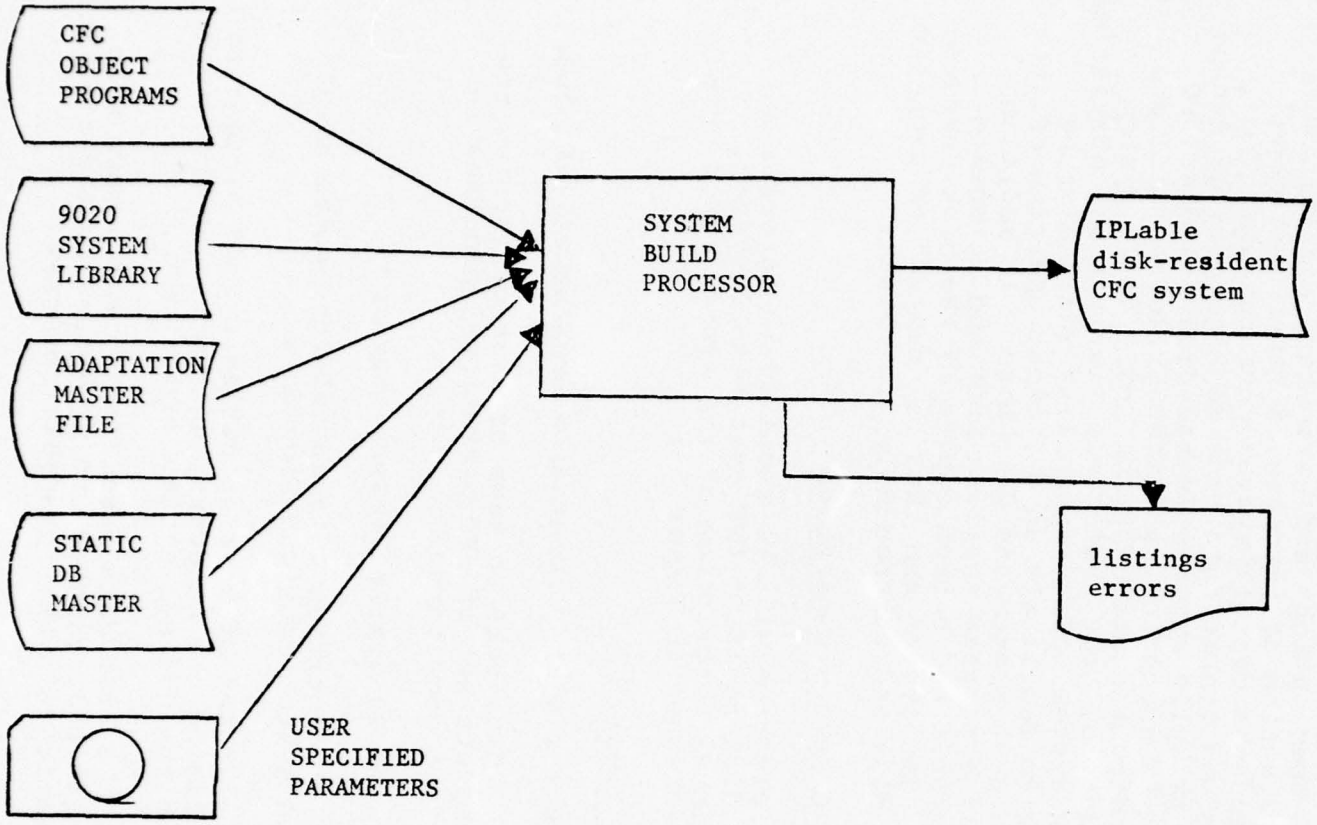

FIGURE 5-1 SYSTEM BUILD

5.1.2 Function

The system generation program will perform the following functions.

a. construct and write disk IPL record

b. read and transfer onto disk the core-resident and disk-resident data sets in core-image form

c. allocate disk space for recovery recording data

d. construct the necessary linkages between programs and storage areas and between programs and hardware devices

e. set storage protect keys

5.1.3 Program Element (PE) Stringing

The PE stringing capability is required to accomplish the stringing (or linking) of appropriate software modules of the CFC applications programs. For this purpose, a PE string is defined as a set of applications software which is required to process one CFC input message (e.g., LIFP, RS, etc.). A PE string may consist of all or some of the CFC applications processes (i.e., Input, Retrieve, Transform, Update, Output).

The system generation program, based on user-defined input specifications, gathers the program modules to be included in each PE, sets up the linkages between these modules, and builds a CFC PE for each CFC message type. In addition, a table is constructed, for subsequent use by the on-line monitor. This table provides the monitor with the mapping and control information needed for on-line loading and scheduling of the PEs.

5.1.4 Output

The output from the system generation program will be:

a. an IPLable disk resident CFC operational system

b. listings containing storage allocation map, cross reference data and system diagnostics

5.2 System Update Capability

The System Update capability will be provided to facilitate an efficient updating of the disk-resident system and data base. This program will make it possible to affect changes in the CFC disk-resident system without requiring a complete system generation run. The changes that can be implemented through the System Update capability include, but are not limited to the following:

a. Insert program patches in the operational system

b. Make changes to the adaptation data base or replace by a new adaptation data base

c. Make changes to the static data base or replace by a new static data base

d. Update system parameters

A system update run will produce a new IPLable CFC disk-resident system. The output listings will contain a record of the changes that were implemented and diagnostic messages (if any).

5.3 Disk Dump/Restore Capability

Support programming must be provided to create transportable copies and backup copies of the disk-resident CFC system. The system can be "dumped" on disk or tape and subsequently "restored" on a disk which can be used to IPL an operational system.

5.4 Automated System Build (ASB)*

The ASB function is currently available and under control of OS/9020 at NAFEC. ASB eliminates, whenever possible, the need for manual intervention required in a system build process. The following sections discuss in summary the major capabilities of ASB.

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* This description of ASB was largely extracted from draft NCP #3847 (ARD-141).

5.4.1 TRIO Generation

A TRIO is defined to consist of four members: compressed source module, object module, compressed language translator listing module, and a cross reference of tables, items and subroutines used by the program. The TRIO Generator produces a new TRIO of a program to be served on permanent storage for subsequent use in System Build. In the Permanent Update Mode, the TRIO Generator updates the master disk data base. Optionally, output listings and punched cards can be produced.

5.4.2 Compool Analyzer

The Compool is a Jovial entity used to define most of the tables referenced by the source modules. If a Compool is changed, any module that references a changed table must be recompiled or reassembled. The Compool Analyzer examines the old and new Compools to determine which tables or items were modified. A list is then produced of all the programs which reference these tables or items. The inventory data set is updated to reflect the requirement to recompile (or reassemble) these programs. The Compool Analyzer also produces a cross reference listing of Compool items vs. programs.

5.4.3 Library Analyzer

The function of the Library Analyzer is to detect changes which may result from an update of the 9020 Library. Such an update may require a recompilation of Library routines and/or user developed application programs. The Library Analyzer checks the new and the old Library master file against the inventory and the cross-reference data sets of the application programs. In addition, the Library Analyzer invokes the proper programs needed to perform any necessary recompliations of Library routines and to update the Library. Output from the Library Analyzer consist of:

a. A listing of Library users which require recompilations due to Library changes.

b. The necessary inputs to the programs needed to perform any recompliations and Library updates.

c. A summary of all programs recompiled due to the Library Analyzer and the reason thereof.

d. A diagnostic listings (e.g., missing items, recursive calls, etc.).

e. A tree structure listings showing the interdependencies between the Library routines.

f. A set of compile listings, TRIOs and an updated Library.

5.4.4 Miscellaneous Functions

Other functions of ASB are:

- Create and maintain a system inventory containing information identifying the system and the programs (e.g., Library, Compool and build ID, data created, TRIO size, responsible organization, programmer ID, etc.).
- Maintain a system catalogue to provide the location of user-created TRIOs.
- Enable only authorized users to be accepted for a build process.
- Move tape resident TRIOs to disk.
- Validate a TRIO prior to inclusion in the build process.
- Scratch unneeded TRIO data sets.
- Enable recovery from an aborted system build process resuming from the last break point before the abend occurred.

6. SYSTEM TEST GROUP

The primary function of the System Test Group is to facilitate program testing, evaluation, and shakedown. Secondary functions include training and demonstration. The simulation capability enables the operation of the CFC system in a controlled environment without requiring actual data, flight plans, site communications, controllers, etc. This is accomplished through the provision of test drivers which produce the stimuli necessary for proper operation of the CFC system. These test drivers generate the inputs which would normally be sent to the CFC system, and simulate the CFC to NAS and the NAS to CFC communication interfacing. The user of the simulation function is provided with the capability to produce off-line any desired scenario for subsequent testing on the CFC system. In addition, simulated events can also be created on-line during a system test run.

This section specifies the functional requirements for the System Test function of the CFC Operational Support System. This function is responsible for accepting keyboard, card, or tape inputs and generating tape outputs with supporting printing/punching. The generated tape is used as input to the CFC operational program to simulate live inputs to the CFC system.

6.1 Interfacility Test Support (INTEP)

6.1.1 Introduction

The primary function of this capability is to facilitate program testing and shakedown (secondary functions include demonstration and training). The use of the simulation tape provides for controlled program testing without requiring actual data, flight plans, site communications, controllers, etc. A simulation tape is a source of simulated real-time inputs to the CFC operational programs.

The INTER function processes user's source data on either cards or tape, and produces a tape containing each type of simulated data in a format compatible with the CFC operational program requirements.

A functional description of the INTER facility is shown in Figure 6-1.

6.1.2 Simulation Tape Generation

6.1.2.1 Modes of Operation

The INTER function will consist of five major subfunctions. Each subfunction will be differentiated by a control card which provides the parameters for that subfunction. The subfunctions will be capable of being executed in any desired order. The subfunctions are:

1. Simulation of NAS inputs
2. Simulation of controller inputs
3. Rerun of operational scenario
4. Printing of simulation tapes
5. Merging of simulation tapes

All subfunctions will check the associated input data for validity. Any error detected will be printed with an applicable error diagnostic. The erroneous data will not be written on the simulation tape. Processing will continue.

6.1.3 NAS Inputs Tape Format and Generation

The symbolic data will be processed and stored on a tape. The generation of the tape is discussed below.

6.1.3.1 Tape Content

The simulation tape will contain the following data:

a. Identification record

b. Time records (indicates start of real-time data)

c. "End of Job" record

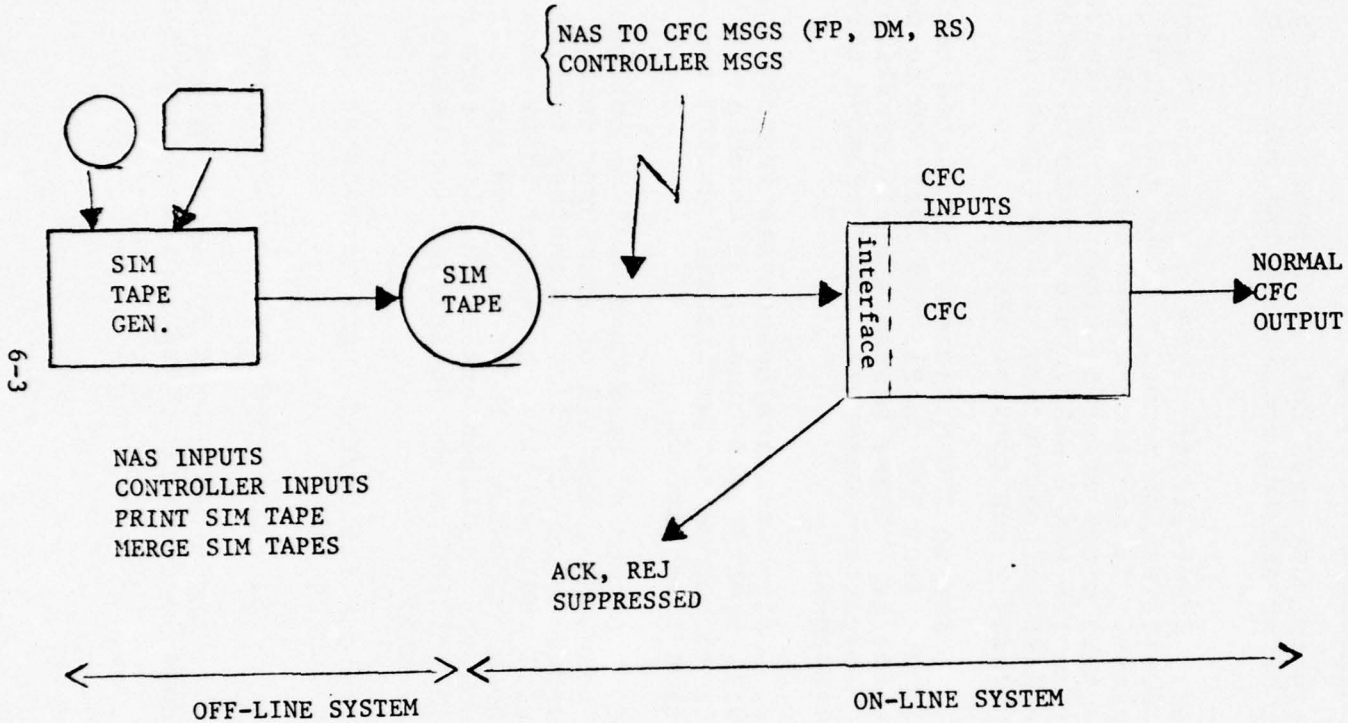

FIGURE 6-1 SYSTEM TEST SUPPORT INTERFACILITY

NAS inputs may be arranged in any order consistent with the requirements for the simulation tape read function.

6.1.3.2 Tape Generation

The program must read Hollerith punched cards, either direct or prestored, containing the following symbolic data:

a. Identification record (control card). The identification record will be the first symbolic entry. It contains a tape identification symbol, a tape clock starting time, and the length of time for which NAS inputs are to be generated. Additional parameters will designate any other necessary run control data.

b. NAS to CFC messages. Simulated real-time inputs from NAS on flights destined to pacing airports. These messages are: FP-flight plans, DM-departure messages, and RS-remove strip messages.

c. Site activate/deactivate indication. This will specify the time(s) at which any site is to become active/inactive during the simulation time period.

d. An end of data card will be optionally included at the end of the input deck. This card, an end-of-file, or another control card, will indicate that the entire input deck has been processed. The simulation run will, however, continue until the final time record (specified in the identification record) is reached.

The tape generation/NAS input processing includes the following tasks:

a. Hollerith card read-in conversion.

b. Input data check for legality and completeness, and output of appropriate diagnostics.

c. Sorting of data into ascending time sequence.

d. Transformation of all correct input data into the correct formats for the operational program(s), and writing of data on the simulation tape.

e. Generation of requested data listings.

f. Generation of optional auxiliary outputs.

6.1.4 NAS Input Processing

The NAS input simulation subfunction will generate NAS to CFC input messages. The following NAS messages will be formulated and written on the simulated tape:

a. Flight Plan message (FP)

b. Departure message (DM)

c. Remove Strip message (RS)

6.1.5 Controller Input Tape Generation

The controller input simulation subfunction will generate a simulation tape containing the CFC controller messages. The controller messages will be stored on a separate tape containing nothing but controller messages. The format of this tape will be consistent with the requirements of the simulation tape read function.

The inputs will be transformed into an appropriate format and then written on the simulation tape.

Format error checking will be performed. An error will not terminate further processing; however, erroneous input will not be included on the simulation tape.

Tape generation/controller input processing includes the following tasks:

a. Hollerith card and/or tape read-in

b. Input data check for legality and completeness; output of appropriate diagnostics

c. Sorting of data into ascending time sequence

d. Transformation of all correct input data into the correct format for the operational program(s), and writing of data on the simulation tape as a time record

e. Generation of optionally requested data listings

The program must read Hollerith punched cards, either direct or prestored containing the following symbolic data:

a. Identification record (control card): The identification record will be the first symbolic entry. It contains a tape identification symbol and a tape clock starting time. Additional parameters will designate any other necessary run control data.

b. CFC controller input messages. Any of the controller messages (e.g., CAPS, LIFP, etc.) can be simulated.

c. An end-of-data command to signal the end of the simulated controller input messages.

6.1.6 Rerun of Operational Scenario

The program shall be capable of reading the system log tape from the on-line system and generating a simulation tape directly from it.

6.1.7 Printing

All simulation printing will be optional, and is divided into two categories:

1. Input data printing

2. Simulation tape printing

6.1.7.1 Input Data Printing

The parameters contained on the NAS input and controller input function control cards will designate the desired input data printing.

Output listings will include the listings of the input card deck in unsorted order or in sorted order according to the user request.

6.1.7.2 Simulation Tape Printing

The printing of simulation tapes will be a subfunction of the simulation. Selectivity of both the amount and the contents of the data to be printed will be available. The parameters designating the amount of printing will be contained on the subfunction control card. Similarly, parameters specifying the contents to be printed will be designated on data cards. Content selectivity will include:

a. Specific messages

b. Specific NAS sites

6.1.8 Simulation Tape Merging

The simulation will have the ability to merge any two or more simulation tapes. Selectivity of the data to be merged from either tape will be available. The parameters designating the tapes to be merged will be contained on the subfunction control card. Similarly, the parameters designating the data to be deleted will be contained on data cards.

6.1.9 CFC-Simulation Tape Interface (CSI)

CSI is a special software interface which will be required in the operational CFC system. This interface will facilitate the testing of the CFC system with the INTER simulation tape. CSI will perform the following functions:

a. Read the simulated messages off the simulation tape, interpret them, and place the information in the appropriate storage buffer(s) for subsequent action by the CFC system.

c. Perform the handshaking functions normally required in accordance with the communications protocol. The ACK and REJ messages produced by CFC will be received by CSI, analyzed and discarded. Similarly, CSI will generate simulated ACK/REJ input messages if and when these are required as input to CFC.

6.2 Intrafacility Test Support (INTRA)

6.2.1 Introduction

The INTRA capability will be used for more extensive testing of the Central Flow Control System (CFC) than is possible with INTER (see Section 6.1). INTRA will aid the user in preparing simulated input to CFC from NAS sites without actually linking CFC to the NAS sites. This simulated input will be sent to NAS over the standard NAS/CFC interface channel hardware.

In addition to providing data from simulated NAS centers, INTRA will print diagnostic listings and input message listings. A functional description of the Intrafacility Test function is shown in Figure 6-2.

6.2.2 System Environment

INTRA will be run on the off-line CE.

System configuration will include the off-line CE and the operational CFC duplex system in a computer-to-computer communication link. The off-line system peripheral equipment (e.g., tape, keyboard) will be used to generate real time NAS messages and to record the CFC to NAS messages (e.g., acknowledgement, rejection).

6.2.3 System Operation

Communication between the operational system that is under test and the INTRA system residing in the off-line facility, for NAS-to-CFC and CFC-to-NAS simulation, will be performed using the standard interface hardware equipment.

6.2.3.1 NAS-to-CFC Communications

The user will be able to build a simulation tape with messages from any specified NAS center without any knowledge of the actual communications protocol between NAS and CFC.

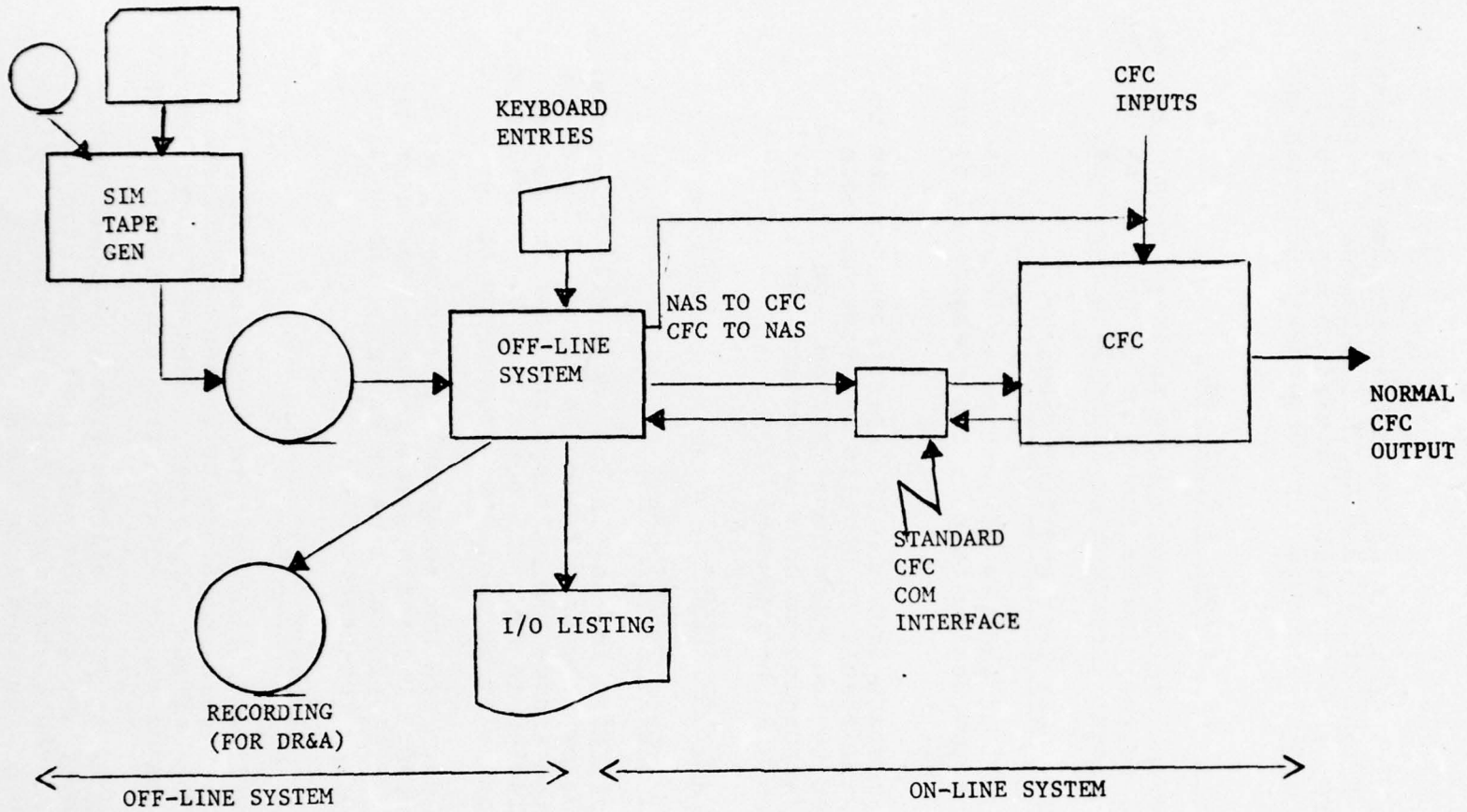

FIGURE 6-2 SYSTEM TEST SUPPORT INTRAFACILITY

When an INTRA-simulated NAS center transmits a message (e.g., flight plan) from NAS and receives a response from CFC, an entry will be stored on tape or disk of the off-line system for subsequent reduction and analysis.

6.2.3.2 Generation of Responses

To test the message checking functions of CFC and the message retransmission functions of NAS, INTRA will be able to issue incorrect or incomplete messages.

6.2.3.3 Data Test and Test Message

INTRA will be capable of sending any test messages from the simulation tape to the operational system under test.

A test message from the CFC operational system to INTRA will result in a valid NAS response being returned to the operational system. On a random basis (according to user parameters) an invalid response will be returned.

6.2.4 System Inputs

6.2.4.1 Card Tape Input

A normal INTRA initialization input file will consist of cards or tape specifying the NAS to CFC message data, the source NAS site and the time for message transmission to CFC. In addition CFC controller messages can also be simulated from cards or tape.

If the data are not acceptable, error messages will be printed. After the error message, the user may correct his error on-line by entering the entire message via the keyboard.

6.2.4.2 Keyboard Input

INTRA will allow the user to enter, via the off-line system keyboard, messages to be sent to CFC from any INTRA-defined NAS center. Similarly, CFC controller messages can be entered from the off-line system.

The inputs to INTRA allowed from a keyboard may be entered by two methods. The user may enter a message live via the keyboard, or keyboard entries may invoke reading of messages from a simulation tape.

6.2.4.3 On-Line Recordings

The on-line recorded data tapes can also be used in order to send simulated messages to the CFC system during an INTRA operation.

6.2.5 System Output

INTRA will record on tape (and optionally list on the off-line printer) each message transmitted to CFC and each response from CFC as it is received. The identification of the NAS center from which the message was sent and the transmission time, will be contained in the message. INTRA will list the input messages as a default option.

The INTRA tape recorded on the off-line system during an INTRA test will be subsequently reducable by a special data reduction program running on the off-line system. The output from this program will provide, according to user specified parameters, complete or selective listings of the messages that are contained on tape and statistics on the volume and frequency of these messages.

Error messages generated by INTRA will be sent to the off-line system printer. An error message will consist of the test time (i.e., HH:MM:SS), a description of the error, and the message that caused the error.

6.3 Automated Unit and String Test Drivers

6.3.1 Introduction

The purpose of the Automated unit and string test drivers in the Central Flow Control System shall be to insure that each subprogram performs as designed before integrating it into the total program. The test program shall be so designed that it will be capable of testing a string of subprograms as well as each individual unit within the string. These tests will be conducted while varying the input parameters.

6.3.2 System

Automated unit and string test drivers will be disk resident programs run on the off-line system under the off-line monitor. No communication with the on-line Central Flow Control (CFC) system will be required for these programs; however, the CFC compool will be used as input.

6.3.3 Operational Concept

Operationally the unit or string undergoing test will be treated as if it were the total operational (on-line) program. This will require that enough of the "on-line" system environment be loaded with the test driver to accommodate the concept.

Input to unit or string tests, as a minimum, will consist of:

1. On-line program environmental data
2. Test control data
3. Utility Programs (i.e., library routines, printout, etc.)
4. Any functions which must be simulated to facilitate testing
5. The unit or string undergoing testing

During operation of the test driver programs it will be possible to vary the pertinent parameters using at least three methods:

1. Pre-stored as test control data
2. Through pre-loaded input devices (e.g., card reader)
3. Under programmer control on-line using such devices as controlled stops to allow manual input.

Output will be completely under control of "Test Control Data" input. The minimum options available will be:

1. Magnetic tape recording
2. Disc Recording
3. On-line print-out

The data recorded by the above methods will be under programmer control through the use of test control data.

6.3.4 Program Load

It will be possible to load the unit or string to be tested and the required support data from a minimum of the following:

1. Magnetic tape
2. Disc
3. Card
4. Any available input device (e.g., input/output typewriter)
5. Any combination of the above.

7. MANAGEMENT AIDS GROUP

The Management Aids Group includes a set of tools which will be used in the overall control of the CFC program development test and maintenance. The CFC system represents a major investment in time and money. Proper and timely control over this effort will help reduce the project cost, improve software reliability and enhance communications between the various project teams.

7.1 Program Evaluation Review Technique (PERT)

PERT is currently being installed at NAFEC under OS/9020. It is planned that PERT will be used as a management planning and control tool throughout the duration of the CFC system development. The purpose of PERT is to help management to:

- logically plan the project
- measure current status
- forecast future progress and problems
- demonstrate the effect of changes on established schedules

The PERT system is a tool which helps in visualizing the progress of the individual project activities from proposal to completion. The continued use of PERT throughout the project will inform management of current or potential future problems which would impact the projected completion date of either the project as a whole or its activities.

7.1.1 Input

PERT accepts user inputs defining all the events and activities in the PERT network. Also provided by the user are various control parameters outlining the optional reports, the title and the date.

7.1.2 Processing

The PERT computer programs process the input data giving accurate information on activity status within the given project. Concise information about time, resource, and responsibility are contained in the various reports generated by the system. Within limits PERT will detect various errors in the input data, such as sequence errors, duplications, events and/or activities which are not logically connected to the PERT network, or loops (events which prohibit the PERT network from reaching the end event).

7.1.3 Output

When processing is complete the reports requested by the user are printed out. The reports provide a variety of useful information. The reports produce listings of events and/or activities sorted by various keys such as preceding or succeeding events, criticality, expected data, responsible organization or allowed date. In addition, error reports are produced, if applicable.

7.2 Program Analyzer

7.2.1 Description

This system is intended to reduce the cost of assuring that software systems written in the JOVIAL language are comprehensively tested. It is comprised of a series of tools which provide

- A means of measuring the effectiveness of both individual and cumulative software test cases
- A capability to facilitate the construction of test data that will thoroughly exercise the software
- An analysis of retesting requirements following software modifications

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* The description of Program Analyzer was largely extracted from Report RADC-TR-76-20, February 1976. The RADC report describe the JOVIAL Automatic Verification System (JAVS).

These tools are intended to be applied during program testing to aid in the exercising of untested program paths and the identification of test cases appropriate to improvement of testing coverage. All of these features are provided by analysis of program structures, instrumentation of the system through insertion of appropriate software probes to measure testing coverage, and comprehensive reports which pinpoint paths in the program structure that remain to be exercised. In addition, guidance is provided for the generation of testcases that will assure coverage of the untested portions. This function can be thought of as a partner during the testing process, supplying a wide variety of automated aids to the user in comprehensive testing activities.

A functional overview is shown in Figure 7-1.

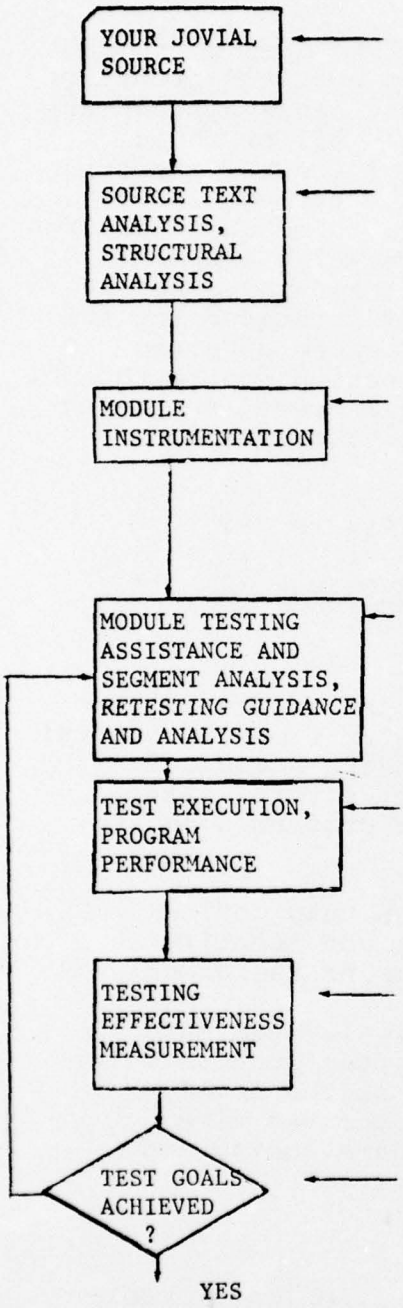
7.3 Hierarchy Plus Input-Process-Output (HIPO)*

7.3.1 HIPO Description

HIPO is a design aid and a documentation technique. It describes the function of a system from the general to the detail level, thereby providing a logical extension of a top-down development effort. It graphically shows what a system or program does and what data it uses and creates.

- As a design aid, HIPO can help define the functional structure and identify the scope of the programming assignment.
- As a documentation tool, HIPO can make a significant portion of the documentation of a system a byproduct of the development process and can reduce the time needed for locating, understanding and altering segments of code.

* The description of HIPO in this section was largely extracted from IBM manual GC20-1851-0.



JOVIAL source code is input for processing and analysis. A special form of comment (optional) inserted by the user directs the Analyzer processing for program performance analysis.

The Analyzer analyzes the code and generates a directed graph of the control structure. (STEP1)
The possible flows through the program are determined. All pertinent data is stored in (STEP2)
a data base for later use. Additional or changed source code causes an existing data base to be updated.

The Analyzer automatically inserts software (STEP3)
probes into the source code to intercept and record program flow during execution. A second type of instrumentation is used to record statistics on program performance according to directives inserted by the user in the source.

The Analyzer provides a variety of services (STEP4)
which assist in the establishing of a (STEP5)
continuing testing strategy both at the detailed level within a module and at the module interdependence level. Test cases are constructed by the user.

Program execution provides normal computa- (TEST)
tional results as well as outputs from the instrumentation. Structural flow output is recorded for later post-test analysis. User-directed program performance output is interspersed with normal program output.

The Analyzer includes detailed post-test (STEP6)
analysis facilities which provide measures of testing thoroughness, both individually and cumulatively for a set of test cases.

The results are examined by the user to determine if test goals have been met and testing is completed.

FIGURE 7-1 AN OVERVIEW OF THE PROGRAM ANALYZER

Source: RADC-TR-76-20

The major objectives of HIPO as a design and documentation technique are to:

- Provide a structure by which the functions of a system can be understood. The diagrams are organized in a hierarchy structure much like an organization chart, where each diagram at any level is a subset of the level above it.

- State the functions to be accomplished by the program rather than specify the program statements to be used to perform the functions.

- Provide a visual description of input to be used and output produced by each function for each level of diagram.

A typical HIPO package contains three kinds of diagrams: a visual table of contents, an overview and detail HIPO diagrams (see Figure 7-2).

1. Visual table of contents - This diagram contains the names and identification numbers of all the overview and detail HIPO diagrams in the package and shows the structure of the diagram package and relationship of the functions in a hierarchical fashion.

2. Overview diagrams - High-level HIPO diagrams, called overview diagrams, describe the major functions and reference the detail diagrams needed to expand the functions to sufficient detail. The overview diagrams provide, in general terms, the inputs, processes, and outputs.

3. Detail diagrams - Lower-level HIPO diagrams contain the fundamental elements of the package. They describe the specific functions, show specific input and output items, and refer to other detail diagrams.

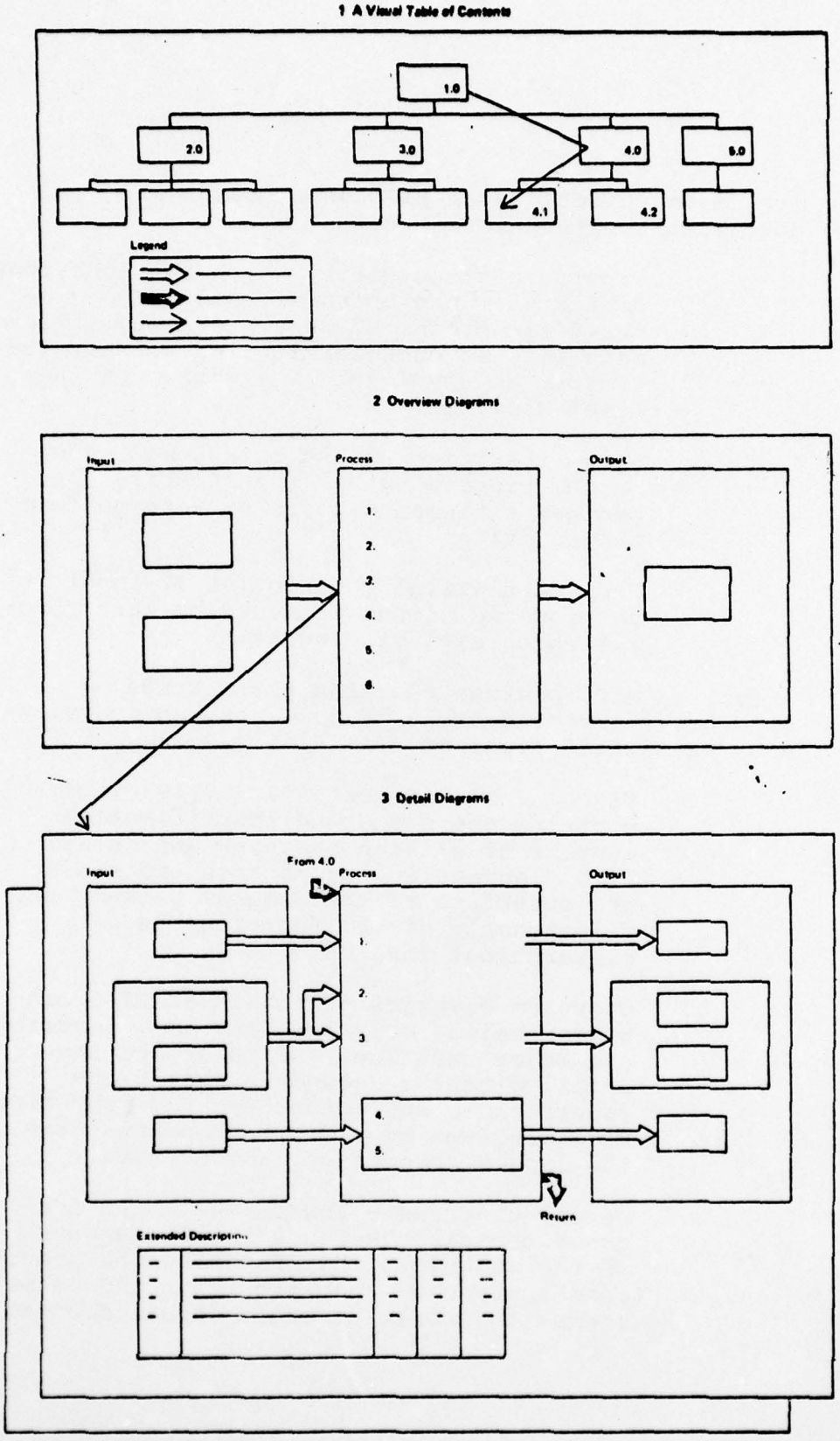


FIGURE 7-2 A TYPICAL HIPO PACKAGE

7.3.2 HIPO Application in CFC

In the CFC development effort, the complete set of HIPO documentation and diagrams will be assembled and maintained as part of the CFC support library. The librarian is responsible for entering all new information into the development support library and to maintain an up-to-date HIPO documentation package. As CFC operational programs are updated and incorporated, within the system build (see Section 5) assembly comprising of all the CFC operational programs, the appropriate HIPO diagrams will be concurrently updated. This will insure that the documentation is current. It will also help reduce the possibility of discrepancies between interfacing modules caused by failure to coordinate changes involving several program modules.

7.4 Automated Code Auditor

7.4.1 Introduction

The constantly increasing cost of producing operationally acceptable computer programs has resulted in a directly proportional increase in the concern of systems managers with code integrity.

In large scale systems, such as the Central Flow Control System, employing many thousands of lines of computer code, there is a gap between achieving diagnostic free compilation and operationally acceptable programs which, traditionally, has been filled by programmer inspection. This has resulted in a situation where it is not uncommon, in large systems, to find large amounts of code which is never exercised by the program as well as large amounts whose only purpose is to correct errors produced by other code.

It is this gap which the automated code auditor is intended to fill.

7.4.2 System

Automated code auditor will be a disk resident program utilizing the "off-line" system. The program will test subprograms as units and strings as well as testing the total program. This will result in an appreciable variation in the off-line system resources required for any specific run of the program. No direct interface with the on-line system will be required; however, some elements of the on-line system, such as compool, will be used for the automated code auditor.

7.4.3 Operational Concept

The automated code auditor will begin with a diagnostic free program element which has successfully passed unit and string testing. It will be designed to audit the program for code integrity by flagging such things as code which cannot be accessed, code which merely corrects other code induced errors, etc.

Input to the automated code auditor will consist of:

1. On-line program environmental data
2. Test control data including simulated flight plans, if required
3. Any required simulated functions
4. The program element undergoing test

Output will include programmer defined items as well as diagnostic messages pertaining to detected coding faults. The minimum options for output will be:

1. Magnetic tape recording
2. Disc Recording
3. On-line print-out

7.4.4 Program Load

It will be possible to load the program element to be tested and the required support data from a minimum of the following:

1. Magnetic tape
2. Disc
3. Card
4. Any available input device (e.g., input/output typewriter)
5. Any combination of the above